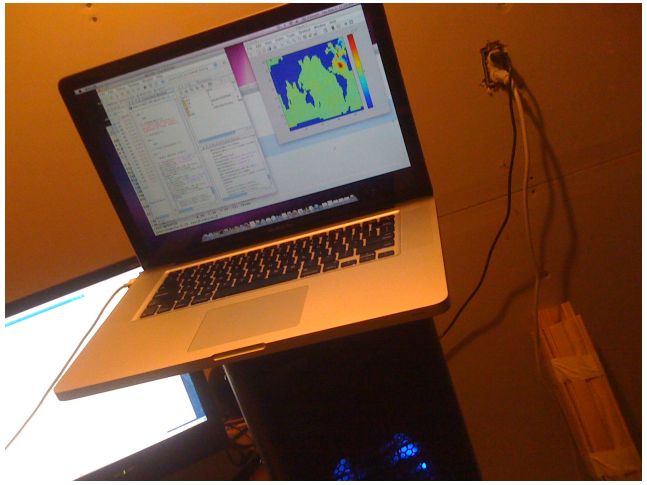
Testing out OpenAD in action - calculating fresh-water impact on North Atlantic with OpenAD.

Chris, Jean and Patrick



Adventures with a totally awesome OpenAD machine in my basement, investigating whether I can use OpenAD to do something interesting.

Background

- Manabe and Stouffer etc… water “hosing”

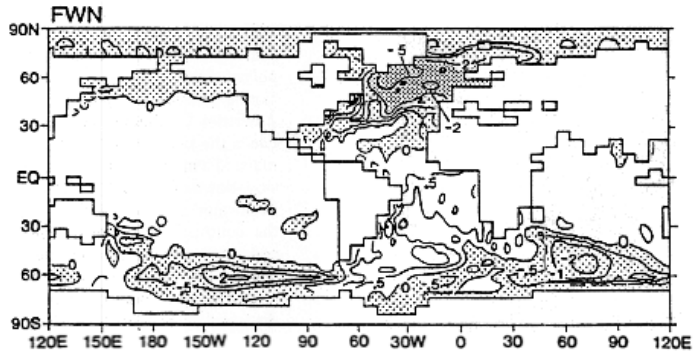
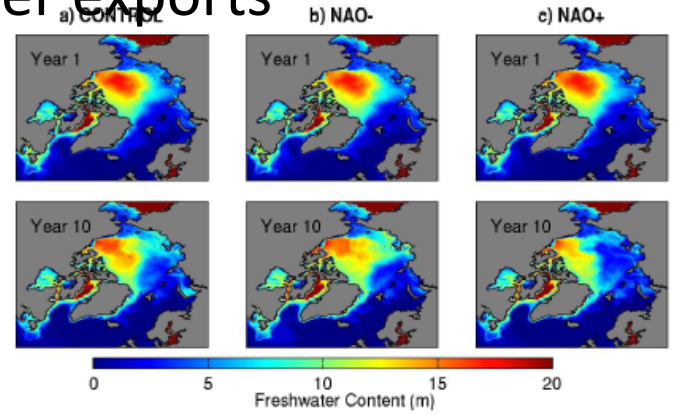
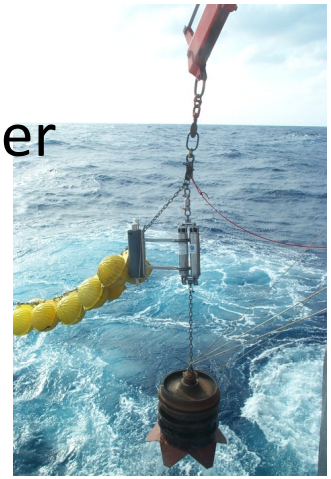


Fig. 6. Geographical distribution of SST anomalies (°C) averaged over year 401–500 of the FWN. The anomalies are defined as the difference between the FWN and the control experiment (from MS97).

- Arctic freshwater exports

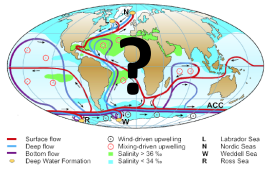


- Would like to know “sensitivity of climate to fresh-water sources (land, arctic sea-ice)”?

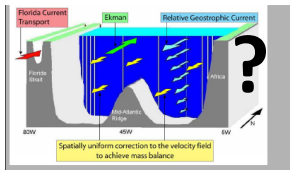


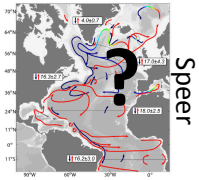
Sensitivity of what?

- MOC – clearly very important, but many people except oceanographers are unsure what this is! Plus, we (along with lots of others) are already working on it with OpenAD – we wanted to test something else!



Kuhlbrot et al

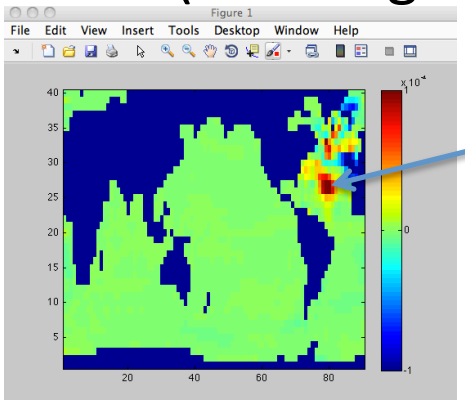




Speer

- Air-sea heat/moisture flux – this is what really sets the weather, as seen for example by palm trees in Ireland. MOC plays an important role in what Qs are, but direct connection is the Qs.

Initial step. Look at sensitivity of north-eastern North Atlantic SST in coarse (four degree), non-coupled, lat-lon (80S-80N) model.



$$\frac{\partial J}{\partial F_W}$$

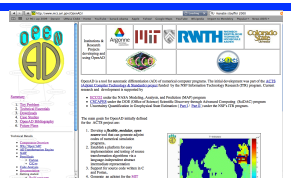
$$J = \overline{\mathrm{SST}}$$

$$J = \overline{\mathrm{SSS}}$$

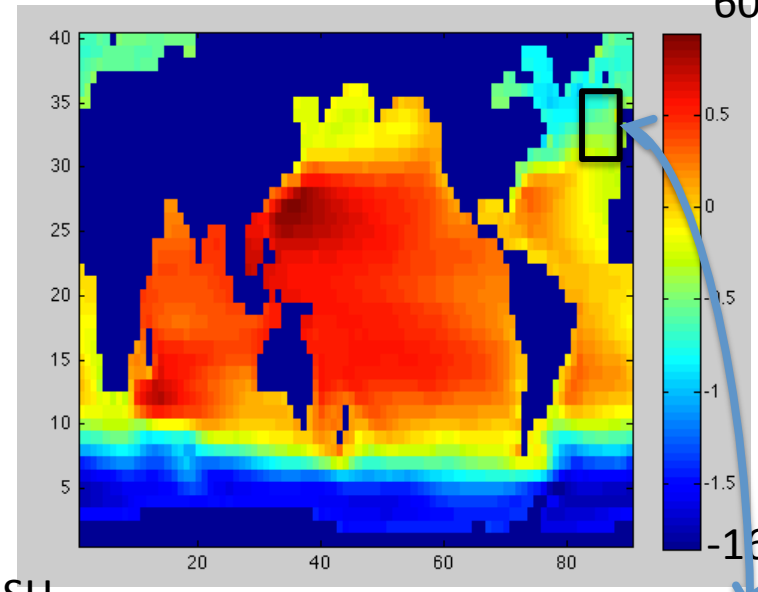
$$J = \overline{\mathrm{C}}$$

Useful for understanding but can also be used as "guide" for cube84 etc… high-res perturbation tests.

Setup (all available at http://mitgcm.org, www.mcs.anl.gov/OpenAD)



- 4 degree ocean
- Initialized from climatology, "forced" with monthly Lev (T,S), Tren (T_x,T_y).
- 80S-80N.



$$J = \frac{1}{A}\iint_A \theta dA$$

Running on beagle – (1) get from mitgcm cvs

```
[cnh@beagle oad_testing]$ env | grep CVS
CVSROOT=:ext:cnh@mitgcm.org:/u/gcmpack
CVS_RSH=ssh
[cnh@beagle oad_testing]$
```

```
      if (   jg .ge. jglo .and. jg .le. jghi
     &        .and. ig .ge. iglo .and. ig .le. ighi ) then
              objf_test(bi,bj) = objf_test(bi,bj) +
     &                           theta(i,j,kLocOut,bi,bj)/pc
      endif
"cost_test.F" [Modified] 105 lines --60%--
```

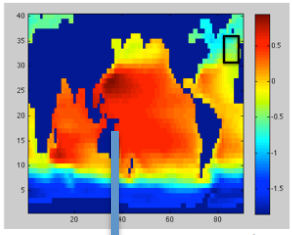
```
./testreport -of ../tools/build_options/linux_ia64_ifort+oad -t OpenAD -oad -ieee
[cnh@compute-3-26 verification]$
```

compile and run

Please wait a few moments while we process your request

First sensitivity test – (4574 seconds later)

$$J = \frac{1}{A}\iint_A \overline{\theta}^{\,t=10\,years}\, dA$$

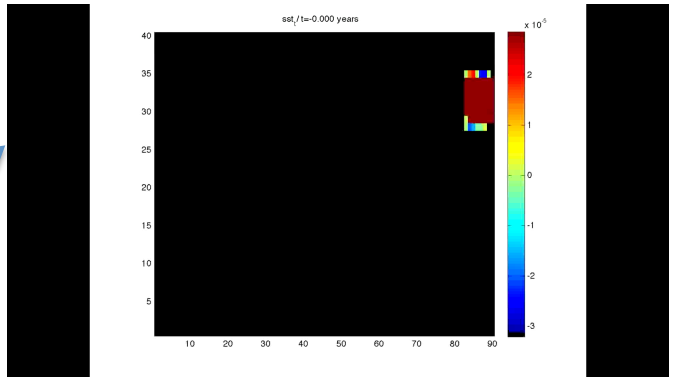


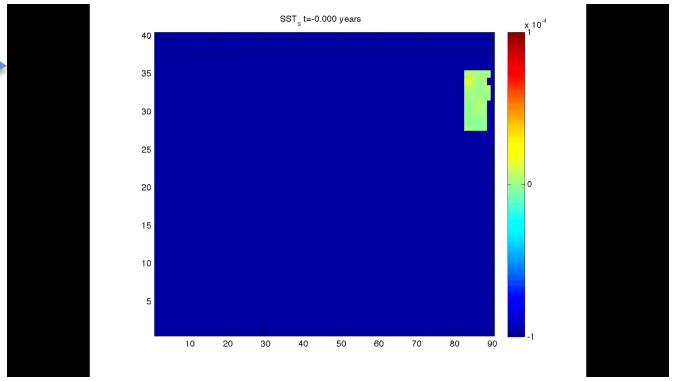
$$J = \frac{1}{A}\iint_A \theta\, dA$$

$$\varphi = \theta$$

$$\frac{\partial J}{\partial \varphi(x,y,z,t)}$$

$$\varphi = S$$





Movies show sensitivity to T,S pulse at t=-T1,T2 etc..
Shows (i) fast kelvin waves, (ii) slower advective and rossby waves. Generally higher sensitivity during winter (due to capping of winter mixing). Zero sensitivity in ice patches during winter T=-1.9. Some areas freshening ➔ cooling, others freshening ➔ warming.
What about sustained source rather than pulse?

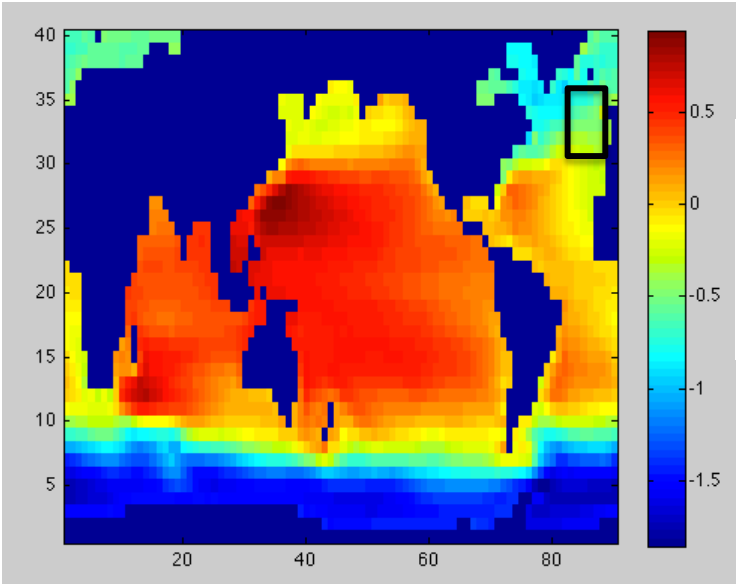
Adding steady source

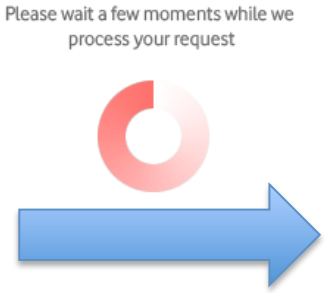
$$\frac{\partial S}{\partial t} = \ldots + \Im(x,y)$$

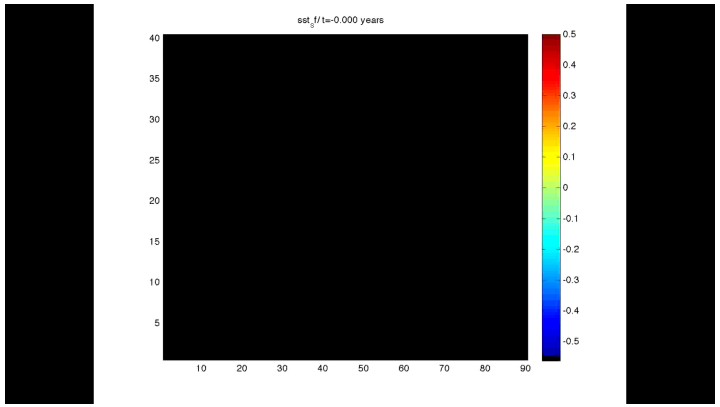
$$\Rightarrow \frac{\partial J}{\partial \Im}$$

Same J as before but add new *independent* variable

```
[cnh@compute-3-26 build]$ vi the_main_loop.F
      c$openad INDEPENDENT(saltflux)
[cnh@compute-3-26 build]$ vi openad_dumpAdjoint.F
foo4=saltFlux%d
call write_fld_xy_rl('adjsf.',suff,foo4,myiter,1)
```







Two regimes clearly visible (1) freshening ➔ cool, (2) freshening ➔ warm NE NATL SST

Also J=f(SSS), planning J=f(tracer) ➔ together can separate buoyancy, advection etc...

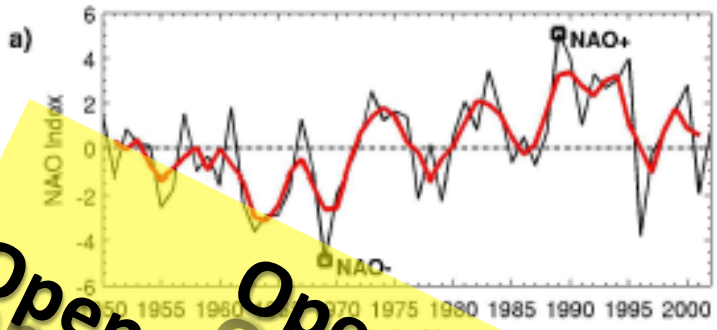
Status summary

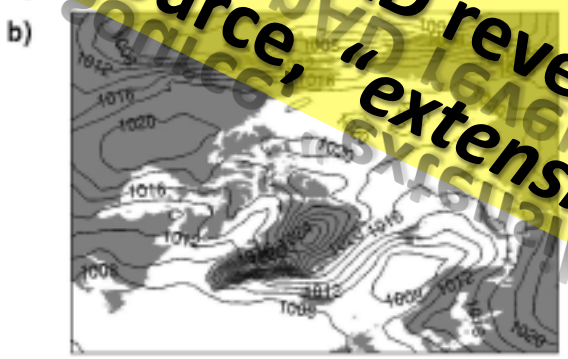
$$\frac{\partial}{\partial F_W}$$

Can't quite do the things indicated by the arrows, but can investigate useful related questions with OpenAD e.g. interesting dipole sensitivity. Examples online at mitgcm.org.

OpenAD reverse mode is usable - today

Open source, "extensible", reasonable perf.





Winter (DJFM) 1989

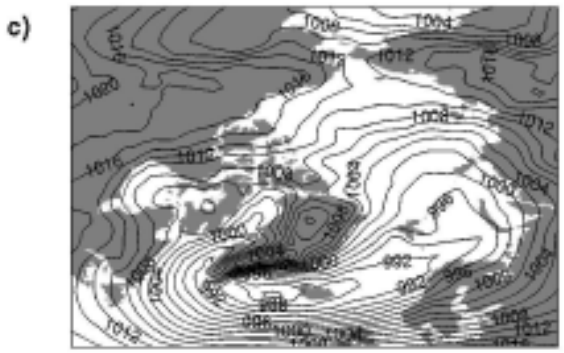


Figure 1. Decadal running averages of seasonal and annual mean temperatures.

Comments on performance

- Four degree test is 90x40x15, single CPU.
  - This is 63% of the cells per CPU of cs510 adjoint on 900 CPU's (adjoint setup for ECCO2).

```
>> 90*40*15/(510*510*6*50/900)
ans =
    0.6228
```

- Wall-clock time per adjoint step (7200 steps) is 0.63 secs (no ice, KPP, simple forcing, no Leith or Daru).

➔ seems to imply wall-clock time for fourteen month sweep of cs510 adjoint at 1200 sec time step (30240 steps) between 8-16 hours?

```
>> 1.61*0.6*30240/3600
ans =
    8.1144
```

"Many terms to add before can draw definitive conclusion. It will get slower, nevertheless this is potentially ***a very good starting point****."* ★★★★★ (4)

Next steps

- Finish current study. Natural FW bc's, cube, robustness to longer spinup, resolution, perturbation experiment validation.

- Tracers, patched global grids (cube etc…), kpp, sea-ice.

- Perturbations in cube84, llcNN, ….